AN OFF-AXIS ZONE-PLATE MONOCHROMATOR FOR HIGH POWER UNDULATOR RADIATION

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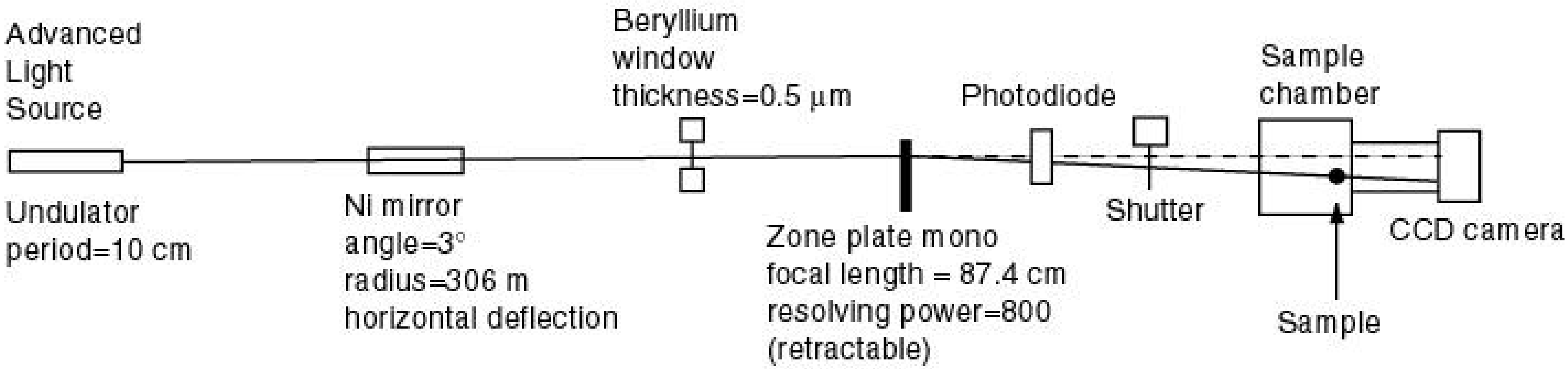
ALS BEAM LINE 9.0.1: COHERENT OPTICS

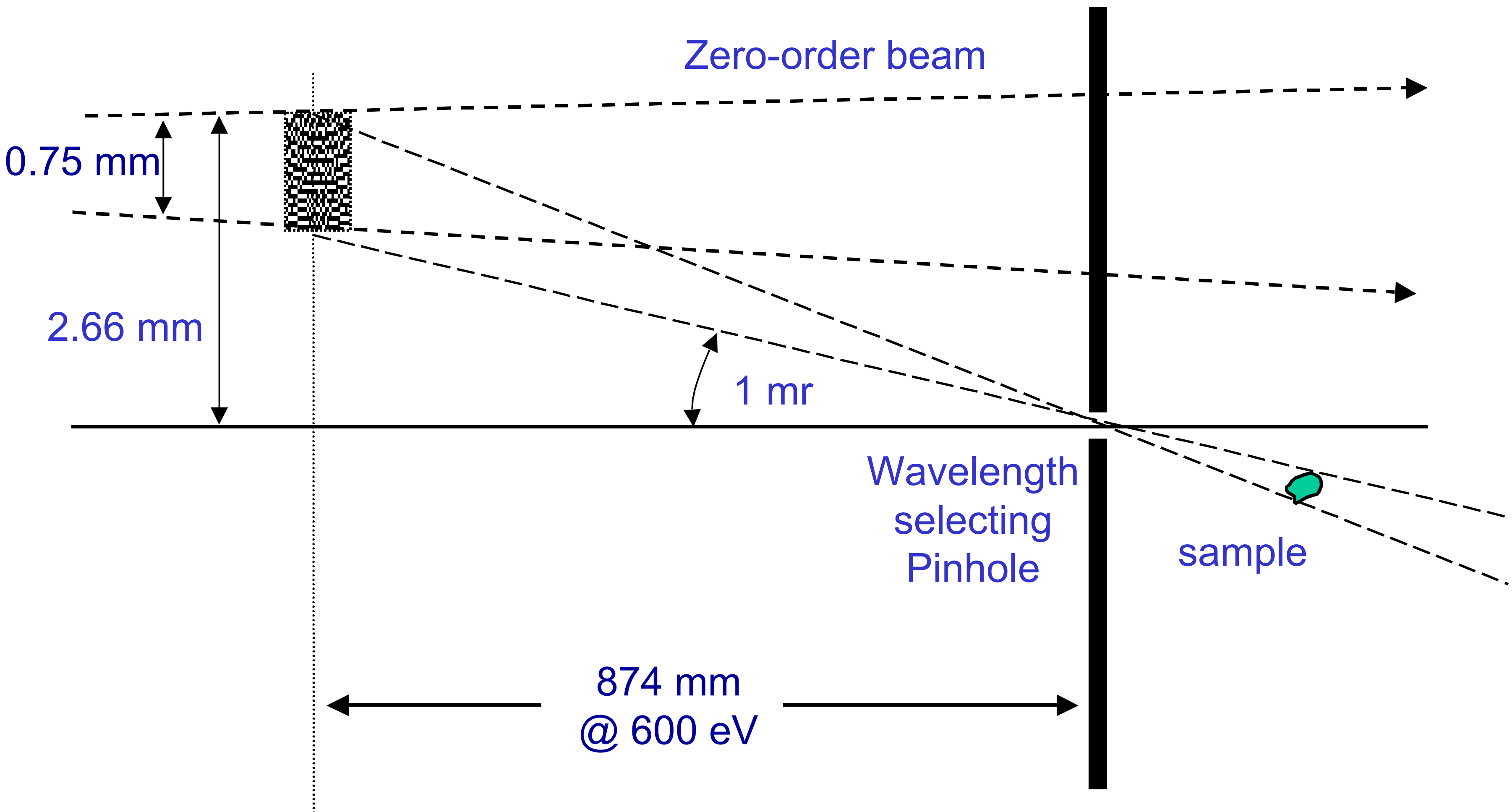


BEAM LINE SIDE VIEW (NOT TO SCALE)

RATIONALE:

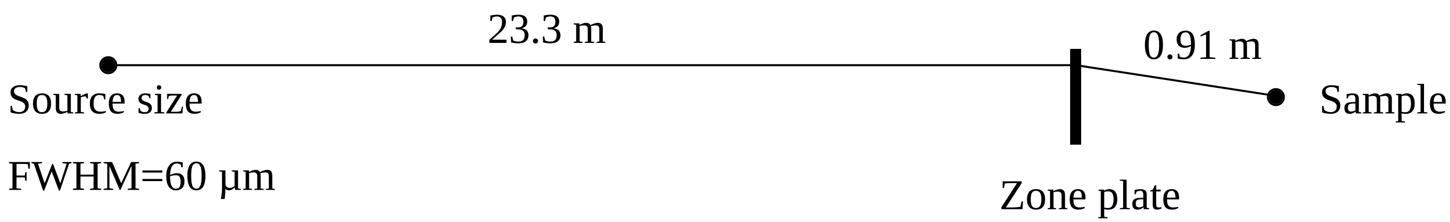
- Experiments are to be done at 588 eV in undulator 3rd harmonic
- Beam is a pink undulator beam with significant power
- Be window is 0.8 mm square which defines the beam size
- Some users require pink beam so monochromator must be retractable
- Resolving power of 800-1000 is required (compared to 100 for the pink beam)

ZONE-PLATE MONOCHROMATOR LAYOUT



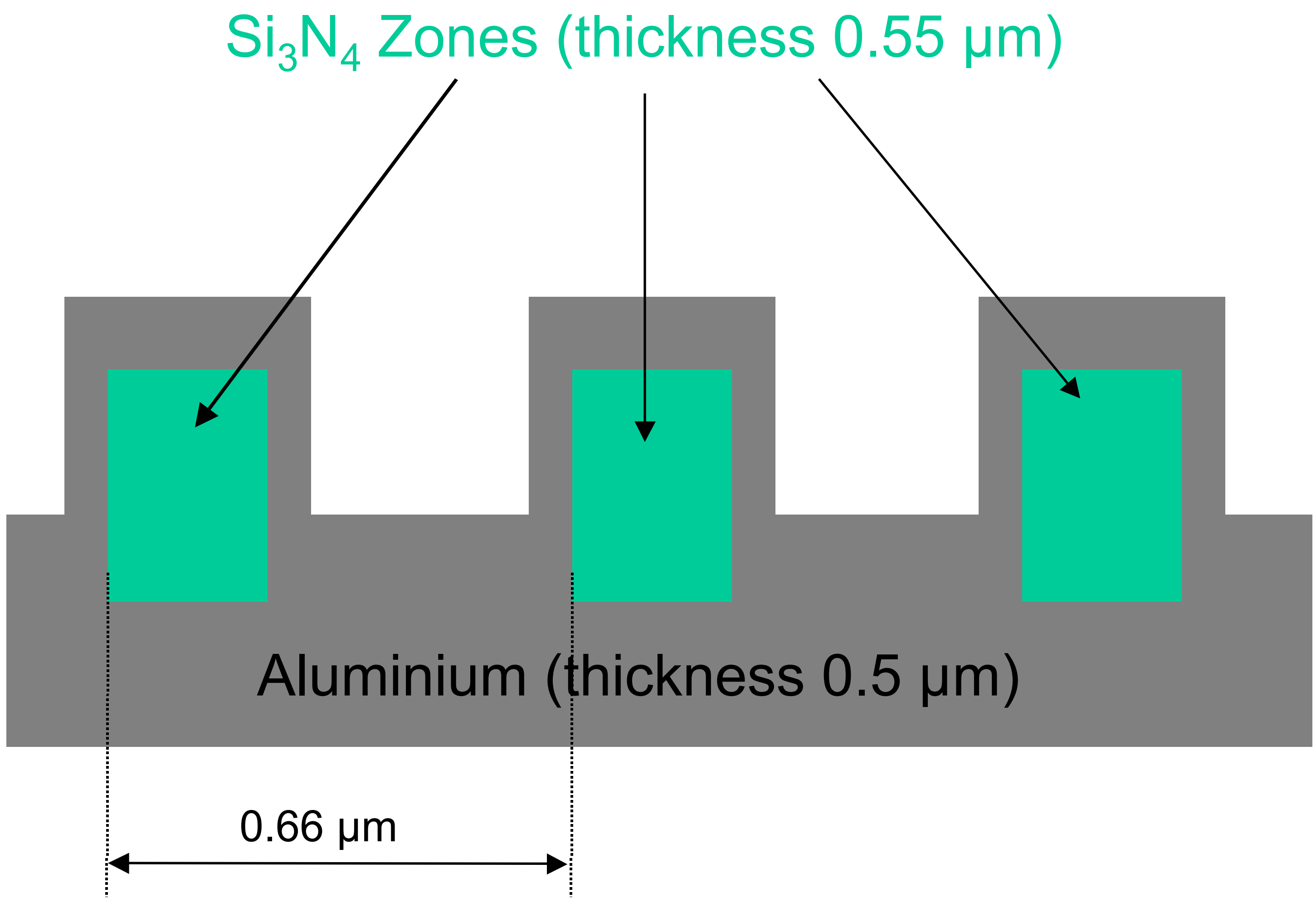
Zone plate diameter *D* with pinhole diameter *d* ➡ resolving power *D/2d*

ZONE-PLATE OPTICS



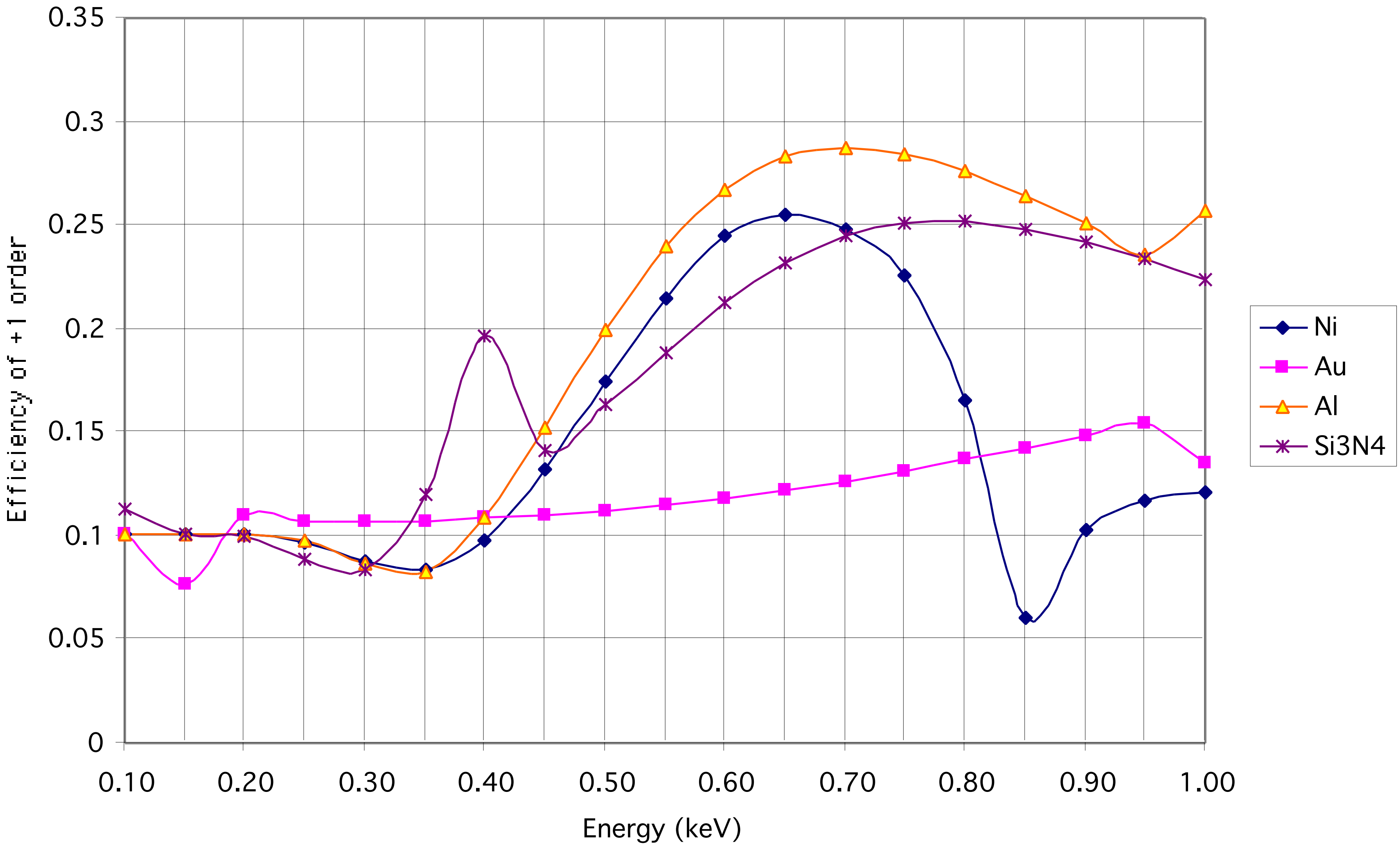
- Zone plate nominal operating energy = 600 eV
- Focal length = 0.874 m
- Vertical demagnification = 25.7
- X-ray vertical spot sizes:
  - Geometrical image size = 2.3 µm
  - Diffraction size = 2.3 µm
  - Combined = 3.3 µm
- Resolving power (based on combined spot size) = 802
- Number of zone plate periods in segment = 1000

ZONE-PLATE STRUCTURE

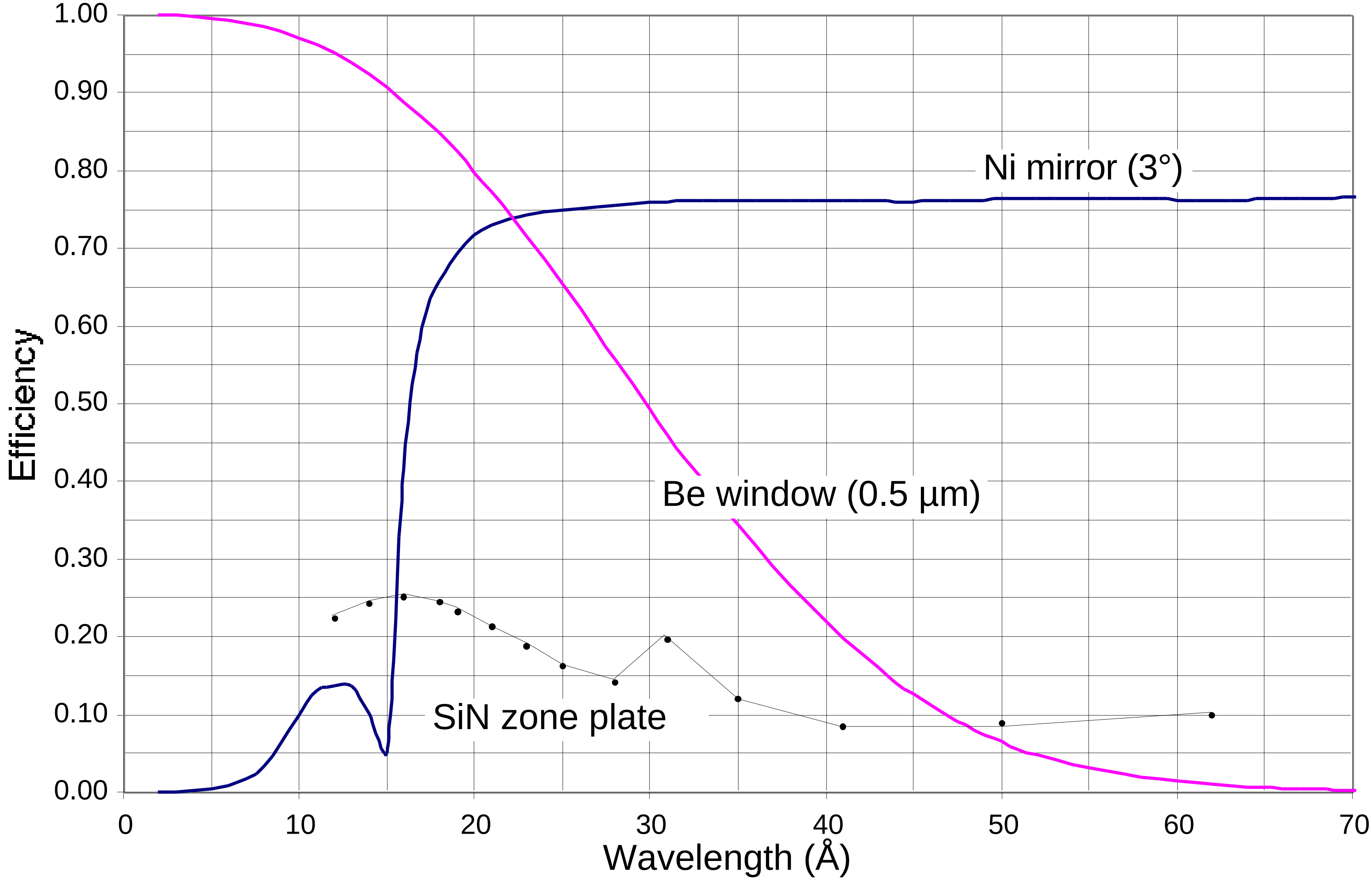


ONLY ROUGHLY TO SCALE

ZONE PLATE EFFICIENCY FOR VARIOUS MATERIALS



EFFICIENCY OF ZONE PLATE ELEMENTS



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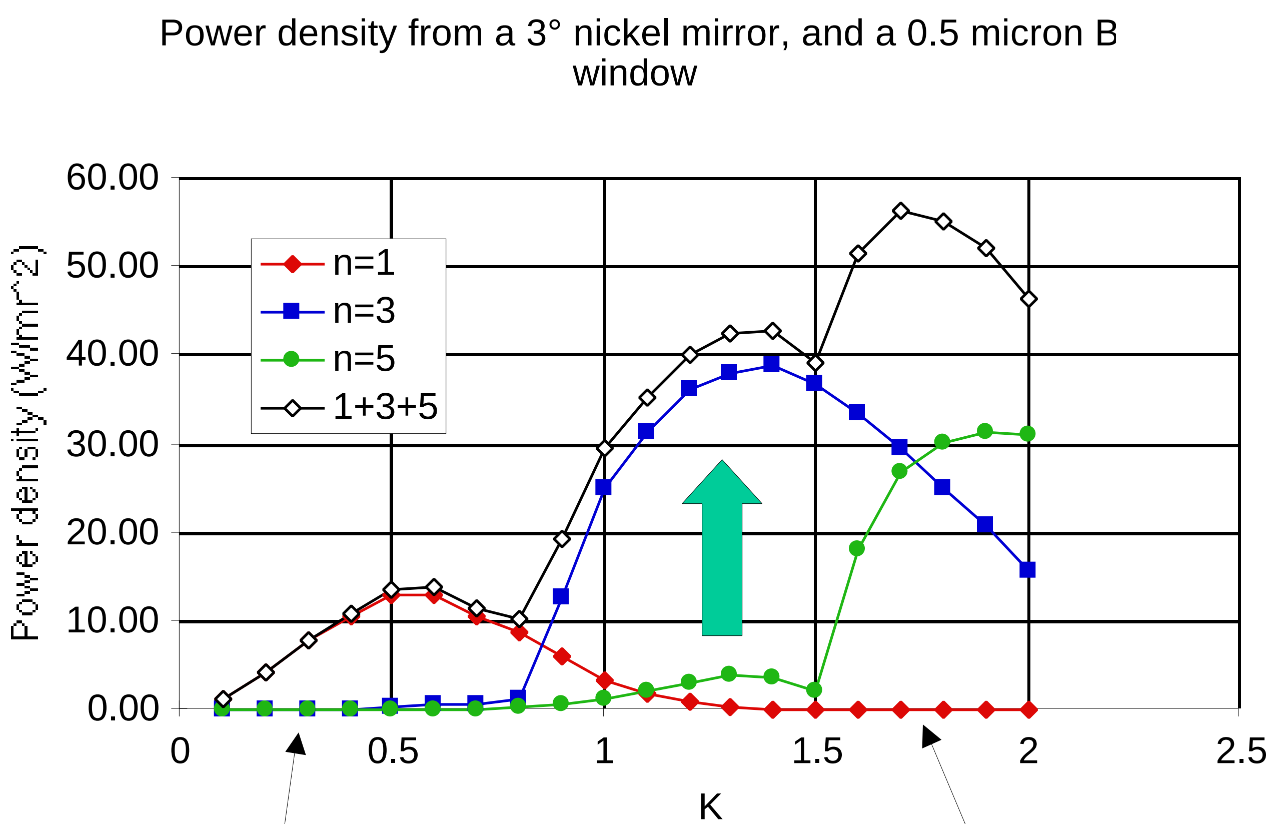
UNDULATOR SOURCE CHARACTERISTICS



5th harmonic killed by mirror

1st harmonic killed by Be window

THERMAL ANALYSIS: THEORY

The Fourier equation for heat flow in 2 - D is

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = -\frac{Q}{k\,t}$$

Q ← abs power/unit area

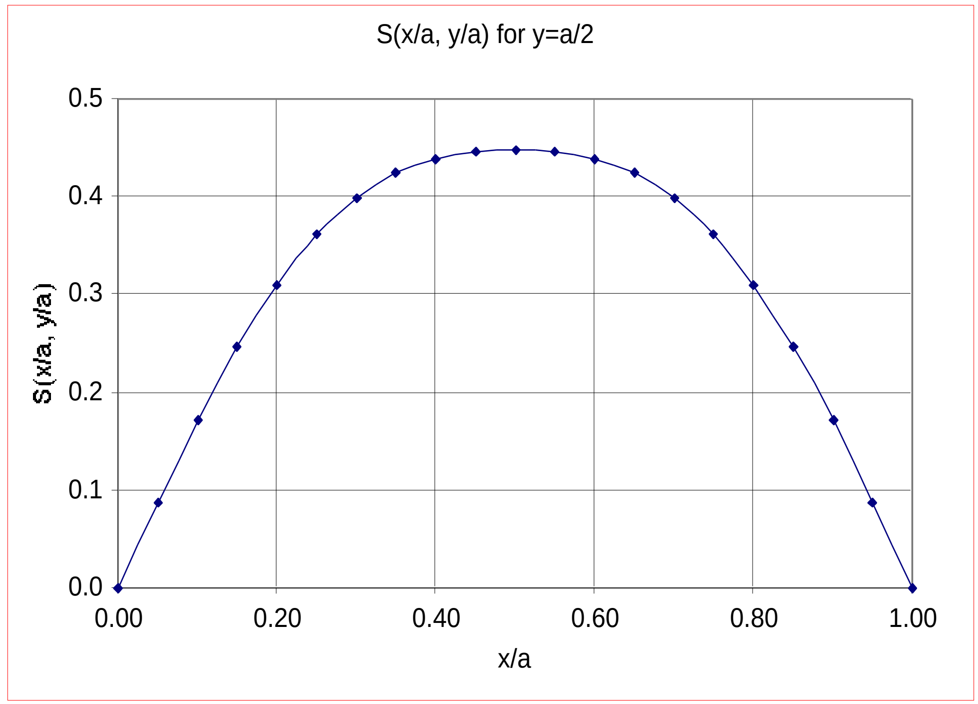
$k\,t$ ← k=conductivity, t=thickness

For a window $a \times b$ with $T = 0$ at the edges and uniform illumination ($Q =$ constant)

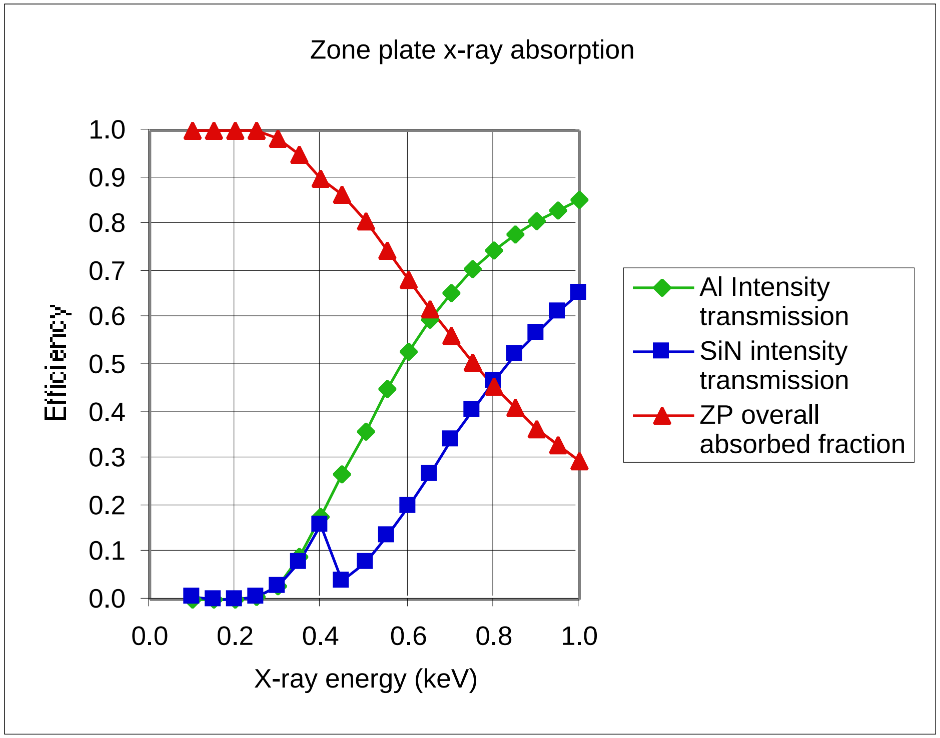
$$T(x,y) = \frac{16Q}{\pi^4 k\,t} \sum_{\substack{m=1 \\ m,n}}^{\infty} \sum_{\substack{n=1 \\ odd}}^{\infty} \frac{1}{mn} \frac{\sin\frac{m\pi x}{a} \sin\frac{n\pi y}{b}}{\frac{m^2}{a^2} + \frac{n^2}{b^2}}$$

For a square window the double sum becomes a universal function $S\left(\frac{x}{a},\frac{y}{a}\right)$ with a maximum $S\left(\frac{1}{2},\frac{1}{2}\right) \approx 0.448$ at the center so

$$\boxed{T_{\max} = 7.17 \frac{Qa^2}{\pi^4 k\,t}}$$



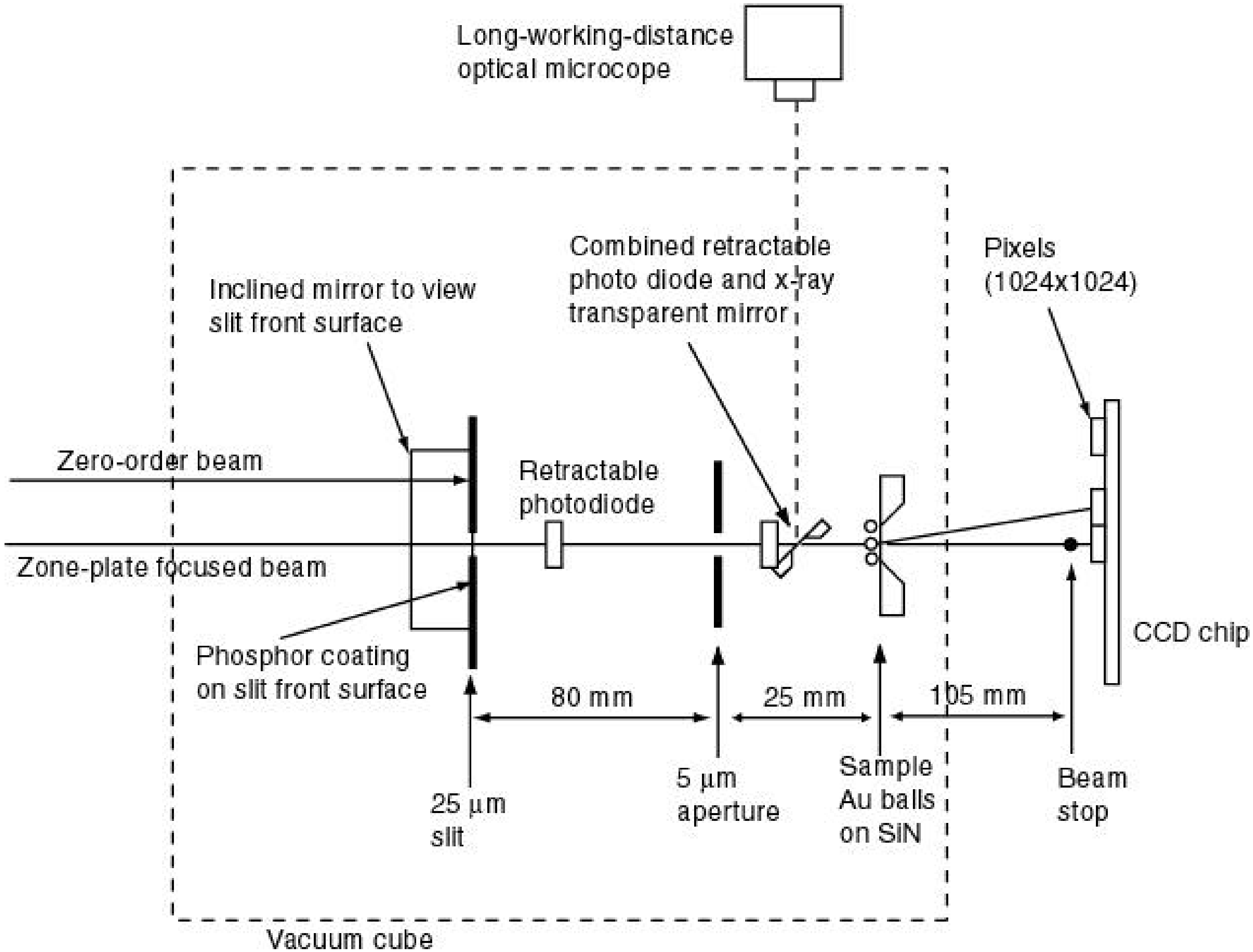
POWER ABSORPTION BY THE ZONE PLATE



Thermal behavior for actual zone plate parameters:
Si_3N_4 thickness = 0.55 µm (π phase shift at 600 eV)
Al thickness = 0.5 µm

- Arriving pink-beam power density:
  - n=1: 0.006 W/mm^2
  - n=3: 0.319 W/mm^2
  - n=5: 0.043 W/mm^2
- Deposited power density = 0.236 W/mm^2
- Calculated center temperature at maximum power load = 80°C relative to the frame as zero
- Normally increasing the thickness of an x-ray window does not improve the power balance between deposition and removal
- But if there is an absorber *other than the window* (in this case the zone-plate rings) then a thickness increase can be beneficial

SOFT-X-RAY DIFFRACTION EXPERIMENT



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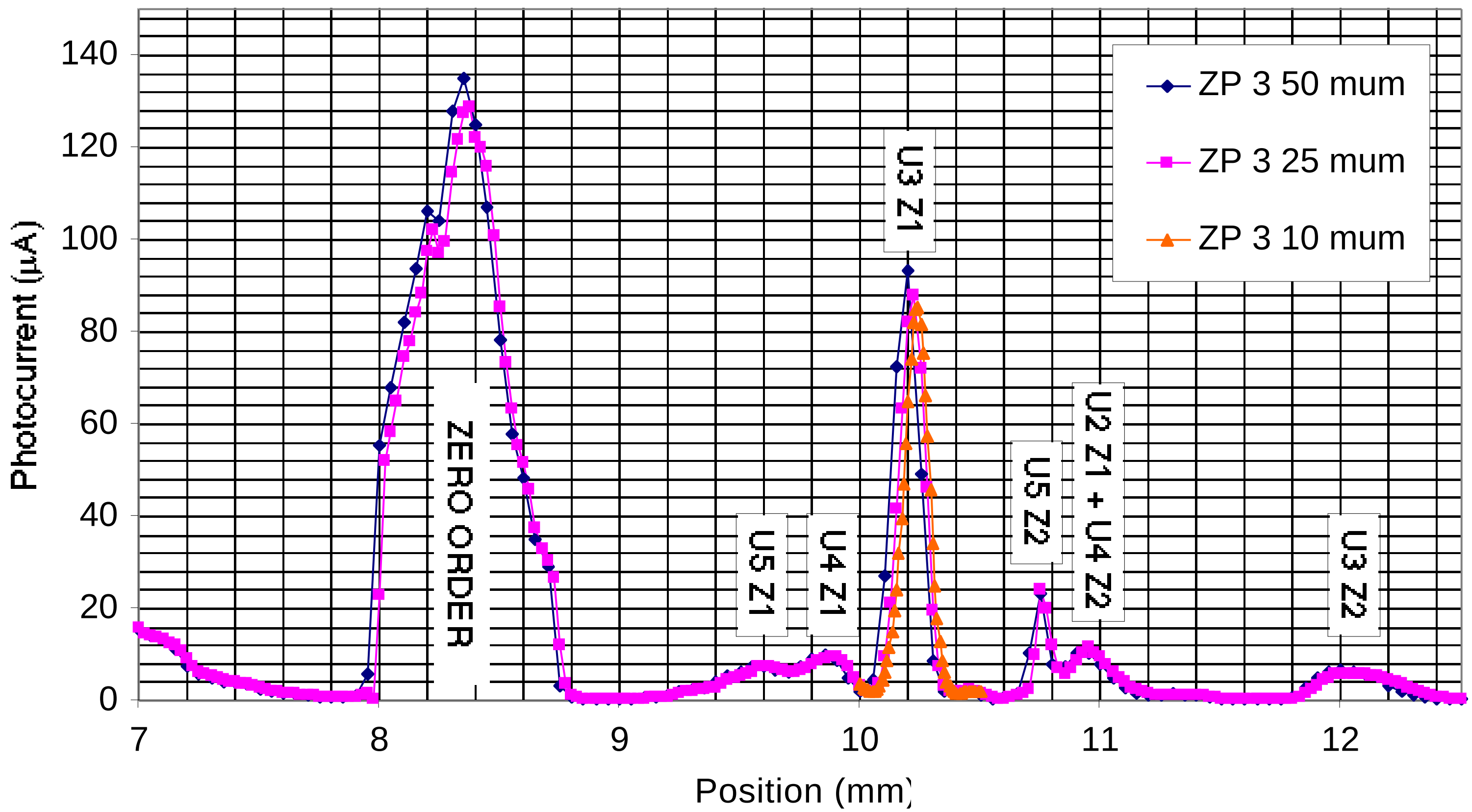
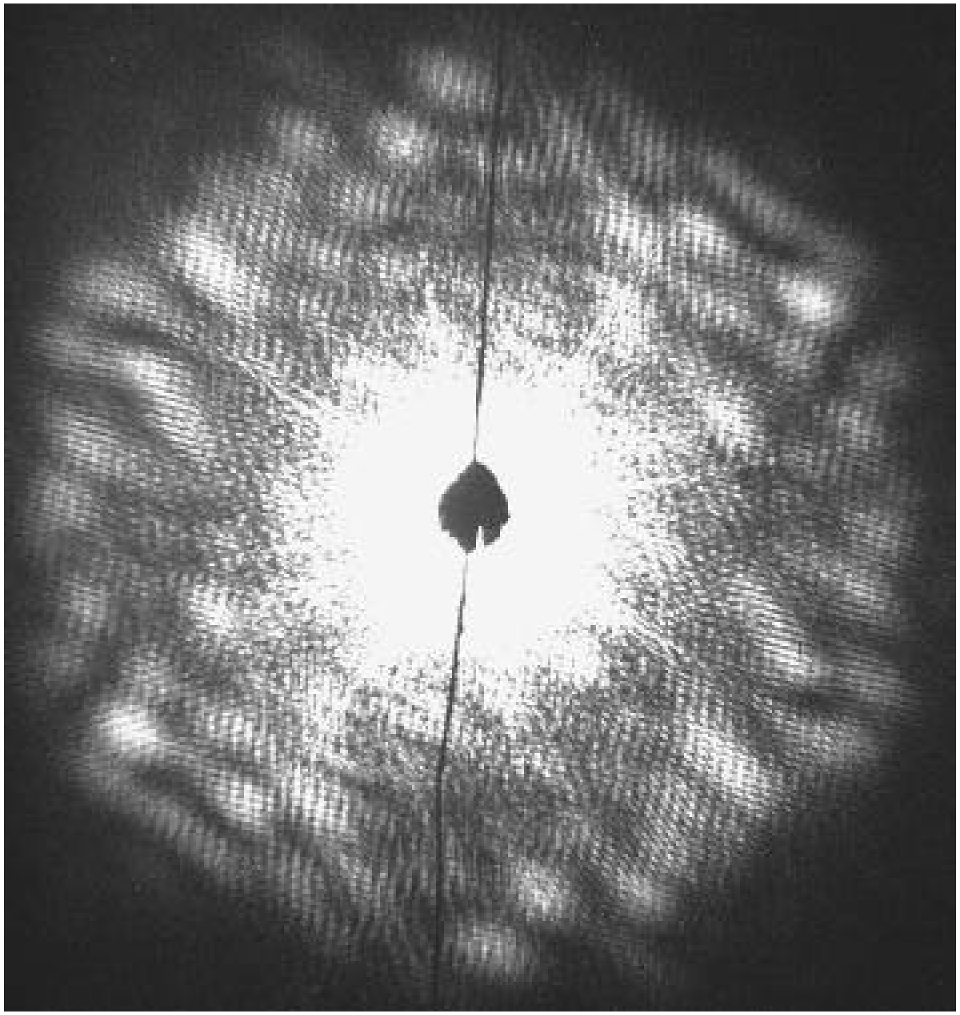
ZONE PLATE POSITIVE-ORDER SPECTRUM



Peak width contributions	• Diffraction: 2.3 µm • Geometrical image: 2.3 µm • Source bandwidth:20 µm • Slit size: 25 µm • Defocus: 90 µm	• Overall calculated value: 96 µm • Measured value: 110 µm

IMPROVED DATA FROM SMALL-WINDOW SAMPLE



- 30 nm gold balls 588 eV
- 1.77x1.77 µm window from window diffraction pattern

- Smaller beam stop
- No merging of data sets
- Good statistics
- Expecting that this will reconstruct by Fienup with no trouble - if not we plan to try the "binary-object" constraint
- Fine and coarse texture gross spacings
- Hexagonal shape from "raft" shape